CORN AND SOYBEAN RESPONSE TO SULFUR APPLICATION ON IOWA SOILS[1]

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Introduction

Historically sulfur (S) application has not been recommended on Iowa soils for corn and soybean production. Prior research has not determined a consistent need for S fertilization in Iowa, with field research indicating no corn or soybean yield response to applied S at virtually every site studied (Thorup and Leitch, 1975; Webb, 1978; Alesii, 1982; Killorn, 1984; Sexton et al., 1998; Mallarino et al., 2000). The soil supply, in combination with sources such as manure and atmospheric deposition has apparently met corn and soybean S needs. Sulfur deficiencies have been reported over the years in various areas of the Midwestern USA, examples including Alway (1940), Hoeft and Walsh (1970), Thorup and Leitch (1975), Rehm (1976), Hoeft (1980), Hoeft et al. (1985), Stecker et al. (1995), and Lamond et al. (1997). However, positive yield responses are often infrequent, for example Hoeft et al. (1985) and Stecker et al. (1995). Responsive sites are most often noted as eroded or low organic matter-coarse textured soils.

The ability of the top six- to seven-inches of soil to supply adequate S has been shown to be low in greenhouse studies where greater response to S application occurs than observed in the field (Dunphy and Hanway, 1972; Widdowson and Hanway, 1974; Hoeft et al., 1985; Sexton et al., 1998). Soil S levels or S supply may become depleted with prolonged crop removal, sulfate leaching, low atmospheric deposition, and declining soil organic matter. Sulfate-S in precipitation, for instance, is considerably lower in Iowa now than thirty years ago (Tabatabai and Laflen, 1976; NADP, 2002). The objective of this study was to determine if corn and soybean would respond to S fertilizer rate and material source at multiple sites across Iowa soils and climatic conditions.

Materials and Methods

This study was conducted in 2000 and 2001 at six Iowa State University Research and Demonstration farms representing major soil areas of Iowa. Site characteristics are listed in Table 1. Corn and soybean crops were grown each year, except at Castana where there was only one crop. The sites had no record of recent manure application. Calcium sulfate and elemental S fertilizers were broadcast applied to corn and soybean at rates of 0, 10, 20, and 40 lb S/acre in the spring of 2000. The sulfur fertilizers were either incorporated with spring tillage or left on the soil surface if the site used no-till. Corn and soybean crops were rotated at each site and the residual response to S fertilizers applied in 2000 was measured in 2001. A complete factorial arrangement of S rate and source was replicated four times in a randomized complete block design. Plot size was 15 or 20 feet wide by 50 feet long. Cultural practices common to the area were used for each crop. Nitrogen application for corn was a product and rate common for the

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area, tillage system, and rotation. Phosphorus and potassium was applied only if directed by soil test. All locations were in a corn-soybean rotation.

Soil samples were collected in the spring of 2000 prior to S application at 0-6, 6-12, 12-24, and 24-36 inch depths and analyzed for sulfate-S by the monocalcium phosphate sulfate-S soil test method (Combs et al., 1998). Soil samples were collected at 0-6 and 6-12 inch depths in 2001 prior to planting from the zero S rate plots and from a composite of both S sources at the 40 lb S/acre rate and analyzed for sulfate-S. Corn ear leaf greenness, leaf opposite and below primary ear, was measured with a Minolta® SPAD 502 chlorophyll meter (Peterson et al., 1993) at the VT growth stage (Ritchie et al., 1986) at all sites except Castana. Corn ear leaves, leaf opposite and below the primary ear (VT growth stage), and soybean leaves, uppermost fully developed trifoliate leaves with petioles removed at onset of the R3 growth stage (Ritchie et al., 1988), were collected for S analysis at all sites except Castana.

Grain was harvested from the middle three to six rows the length of the plots. Reported grain yields were corrected to standard moisture – 15.5% for corn and 13% for soybean. Grain samples (all sites but Castana) were analyzed by near infrared spectroscopy (NIR) for protein concentration (corrected to standard moisture) by the Iowa State University Grain Quality Lab using the procedure of Rippke et al. (1995).

Results and Discussion

Sulfur application in 2000 had no statistically significant effect on corn or soybean grain yield at any site in 2000 (Table 2). Residual-year S (from the S fertilizers applied in 2000) had no statistically significant effect on corn or soybean grain yield at any site in 2001 (Table 3). High winds and plant lodging may have contributed to corn yield variability measured in 2001 at Kanawha. This study was not a statewide survey of potential response across Iowa, so it is possible that specific soils or soil situations may respond positively to S application. However, these results are consistent with those of recent research conducted in Southwestern, Western and Northwestern Iowa at Iowa State University Research and Demonstration Farms and in producers fields with field-length comparison strips (Sexton et al., 1998; DeJong, 1998; Mallarino et al., 2000; C.R. Olsen and C. McGrath personal communication, 2000); and with the results of statewide studies conducted previously in Iowa (Webb, 1978; Killorn, 1984).

Chlorophyll meter readings of the corn ear leaf did not change with S rate at any site in either year (individual site data not shown). Mean chlorophyll meter readings of the corn ear leaf (mean across all sites) did not change with S rate or source in either year (Table 4). At Ames in 2001, corn plants showed early-season yellowing and leaf striping on the zero S rate plots. However, visual symptoms disappeared as the season progressed and no chlorophyll meter reading or yield difference was measured.

Averaged across all sites, corn and soybean leaf S concentrations were significantly increased by addition of S in 2000, but only for corn in 2001 (Table 4). The increase in S concentration was not large, approximately 0.02% increase for corn and soybean. For corn, the mean leaf S concentrations across all sites were lower than the 0.21% level considered sufficient by Neubert et al. (1969), and at individual sites were above this level only at Ames in 2000 (data not shown).

Leaf S concentrations below 0.21%, however, have not always been indicative of S response, for example Reneau and Hawkins (1980) and Stecker et al. (1995). Corn leaf S concentrations were lower in 2001 than 2000 (Table 4). A significant S rate effect on corn leaf S concentration was measured at all sites but Ames and Doon in 2000, and at all sites but Crawfordsville in 2001 (data not shown). The lowest S concentration without applied S was measured at Ames in 2001 (0.14%). The increases in corn leaf S concentration did not translate to an increase in leaf chlorophyll meter readings (leaf greenness) or grain yields. For soybean, the mean leaf S concentrations across all sites were within the sufficiency range of 0.20 - 0.40% reported by Mills and Jones (1996), and were not below this range at any site in either year. Soybean leaf S concentrations were lower in 2001 than 2000 (Table 4). At individual sites, a significant effect due to S rate was only measured at Ames in 2000 (data not shown), with the soybean leaf S concentration at that site increasing from 0.23 to 0.28% (control and 40 lb S/acre rate). The increases in soybean leaf S concentration did not translate to an increase in grain yields.

Corn and soybean grain protein was not increased by application of S, either averaged across all sites (Table 4), or at individual sites (data not shown). Protein levels were similar both years.

Soil sulfur concentrations (extractable sulfate-S by the monocalcium phosphate method) in the spring of 2000 were variable between sites and soil depths (Table 5). Sulfate-S concentration increased slightly with depth, although there were differences in this trend between sites. In 2001, similar sulfate-S concentrations were measured (control plots) in the 0-6 inch depth sample as in 2000. Sulfur applied at 40 lb S/acre in 2000 increased sulfate-S concentrations in the spring of 2001 (mean 2.5 ppm increase with 40 lb S/acre in the 0-6 and 6-12 inch soil depths). An extensive analysis of profile sulfate-S (5-foot depth) in Iowa soils by Alesii (1982) indicated a wide range in amount of sulfate-S, with most soils containing large amounts. The samples collected to three feet in this study also indicate a range in sulfate-S, with a trend in amount similar in the same soil associations as measured by Alesii (1982). There was no relationship between the three-foot profile sulfate-S and leaf S concentration or yield response.

Although extractable levels in the 0-6 inch depth at several sites were lower than the reported 10 ppm critical level (Hoeft et al., 1973) each year, there was no response in crop yield. Since no site had a significant yield increase to applied S, neither sites with high nor low sulfate-S concentrations in the top six inches of soil responded to applied S. This illustrates a common occurrence found in S research trials; soils with high sulfate-S concentrations in the top six- to seven-inches of soil indicate no response to applied S, but at the same time soils with low sulfate-S concentrations do not reliably predict a response.

Conclusion

The lack of corn and soybean grain yield increase to S application was consistent across fertilizer materials, rates, and sites in both years of this study. These results are consistent with multi-year and multi-site field research conducted for 30+ years in Iowa. It appears that combined S supply from soil profile sulfate, atmospheric deposition, crop residue and organic matter mineralization continues to meet crop requirements and will do so in the foreseeable future. Sulfur fertilization is not expected to improve corn and soybean yield across the preponderance of Iowa soils.

Although not a component of this study, manure currently being applied to large crop acreage in Iowa is an important S input and should further lessen the need for S fertilization.

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Table 1. Site characteristics.

Site	General Location	Soil Name	Soil Organic Matter	Tillage System
			%	
Ames	Central	Clarion l; Nicollet l	4.0	Chisel/Disk/Field Cultivate
Atlantic	Southwest	Marshall sicl	3.7	No-Till
Crawfordsville	Southeast	Taintor sicl; Mahaska sicl	5.0	Chisel/Disk/Field Cultivate
Doon	Northwest	Moody sicl	4.1	Chisel/Disk/Field Cultivate
Kanawha	North Central	Canisteo cl; Nicollet l	6.7	Chisel/Disk/Field Cultivate
Castana	Western	Monona sil	3.3	No-Till

Table 2. Effect of sulfur source and rate on corn and soybean grain yield, 2000.

	Ames		Atlantic		Crawfordsville		Doon		Kanawha		Castana	
S Rate	CaS†	S†	CaS	S	CaS	S	CaS	S	CaS	S	CaS	S
lb S/acre	- - - - - -	- - - - - -	- - - - - -	- - - - - -	- - - - - -	- - - bu/acre	- - - - - -	- - - - - -	- - - - - -	- - - - - -	- - - - - -	- - - - - -
Corn												
0	175	179	150	150	172	158	154	144	159	159	159	163
10	180	174	146	150	157	167	143	148	161	156	160	161
20	174	176	152	152	170	164	142	143	156	160	155	156
40	177	175	147	149	151	161	144	147	163	162	163	163
	NS‡		NS		NS		NS		NS		NS	
Soybean												
0	53.8	54.2	47.5	46.6	51.4	52.3	43.5	43.1	52.5	52.7	---	---
10	53.9	53.4	46.3	48.5	51.2	49.7	42.4	42.6	51.7	52.6	---	---
20	52.8	55.0	46.3	45.5	50.0	50.2	39.9	44.3	53.1	53.1	---	---
40	50.4	54.5	46.4	47.4	51.0	49.5	42.3	43.8	53.1	51.7	---	---
	NS		NS		NS		NS		NS		---	

† CaS = calcium sulfate; S = elemental sulfur. Sulfur fertilizers applied spring 2000.

‡ No significant effect due to S rate, source, or interaction ($P \leq 0.05$).

Table 3. Effect of sulfur source and rate on corn and soybean grain yield, 2001.

	Ames		Atlantic		Crawfordsville		Doon		Kanawha		Castana	
S Rate	CaS†	S†	CaS	S	CaS	S	CaS	S	CaS	S	CaS	S
lb S/acre	- - - - - -	- - - - - -	- - - - - -	- - - - - -	- - - - - -	- - - bu/acre	- - - - - -	- - - - - -	- - - - - -	- - - - - -	- - - - - -	- - - - - -
Corn												
0	159	159	147	147	118	111	145	142	164	173	--	--
10	154	156	145	152	110	109	138	141	169	177	--	--
20	158	164	148	147	113	117	141	138	175	177	--	--
40	155	153	147	147	118	108	143	144	180	166	--	--
	NS‡		NS		NS		NS		NS		--	
Soybean												
0	40.3	41.1	46.7	43.9	54.8	54.5	44.8	44.2	53.5	53.7	44.3	43.0
10	43.3	40.2	44.7	45.0	54.7	54.5	43.2	43.4	52.6	52.3	44.5	46.5
20	39.4	41.1	45.5	46.5	56.5	57.1	42.3	43.6	51.4	52.7	42.5	47.3
40	39.4	39.5	45.8	46.4	54.3	54.2	40.9	44.6	51.8	52.3	44.0	40.3
	NS		NS		NS		NS		NS		NS	

† CaS = calcium sulfate; S = elemental sulfur. Sulfur fertilizers applied spring 2000.

‡ No significant effect due to S rate, source, or interaction ($P \leq 0.05$).

Table 4. Effect of sulfur source and rate, mean across all sites in 2000 and 2001.

	Corn								Soybean					
	Grain Yield		Chlorophyll Meter Reading		Leaf S		Grain Protein		Grain Yield		Leaf S		Grain Protein	
S Rate	CaS[†]	S[†]	CaS	S	CaS	S	CaS	S	CaS	S	CaS	S	CaS	S
lb S/acre	bu/acre				%		%		bu/acre		%		%	
2000														
0	162	159	60	60	0.18	0.18	8.0	8.0	50.0	50.1	0.26	0.27	35.5	35.7
10	158	160	60	60	0.19	0.18	7.9	8.1	49.3	49.6	0.27	0.26	35.6	35.4
20	158	159	60	60	0.19	0.18	8.0	8.0	48.9	49.7	0.28	0.28	35.5	35.6
40	158	159	60	60	0.20	0.20	8.0	8.0	49.0	49.6	0.29	0.27	35.4	35.5
	NS[‡]		NS		SS[§]		NS		NS		SS[¶]		NS	
2001														
0	147	146	62	62	0.15	0.15	8.0	8.1	48.0	47.8	0.25	0.25	35.4	35.3
10	143	147	62	62	0.16	0.15	8.1	8.2	48.1	47.6	0.25	0.25	35.3	35.3
20	147	149	61	62	0.17	0.17	8.1	8.1	47.0	48.5	0.24	0.25	35.2	35.5
40	149	144	62	61	0.17	0.17	8.1	8.1	46.6	46.9	0.24	0.26	35.1	35.2
	NS		NS		SS[§]		NS		NS		NS		NS	

[†] CaS = calcium sulfate; S = elemental sulfur. Sulfur fertilizers applied spring 2000.

[‡] No significant effect due to S rate, source, or interaction ($P \le 0.05$).

[§] Significant mean effect due to S rate ($P \le 0.05$).

[¶] Significant S rate x source interaction ($P \le 0.05$).

Table 5. Extractable S concentration by the monocalcium phosphate sulfate-S soil test method, spring 2000 and 2001.

Sample	Ames		Atlantic		Crawfordsville		Doon		Kanawha		Castana	
Depth	Crn[†]	Sb[†]	Crn	Sb	Crn	Sb	Crn	Sb	Crn	Sb	Crn	Sb
inches	ppm											
2000[‡]												
0-6	9	5	8	11	6	7	2	4	7	7	4	--
6-12	6	6	11	5	2	4	2	4	4	7	5	--
12-24	9	5	7	7	2	5	8	7	10	15	2	--
24-36	13	11	7	10	3	2	--	--	9	10	4	--
2001[§]												
0 lb S/acre												
0-6	10	10	8	12	3	8	2	3	8	6	--	6
6-12	5	9	1	4	6	3	2	3	12	7	--	6
40 lb S/acre												
0-6	15	14	18	14	6	6	2	6	9	7	--	8
6-12	9	11	4	5	3	10	7	10	13	6	--	5

[†] Crn = Corn grown in 2000; Sb = Soybean grown in 2000. Crops rotated in 2001.

[‡] Soil sampled before sulfur application, spring 2000.

[§] Composite sample from both S sources, spring 2001.